



Wind farm Control with Power System Support

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Wind farm control with power system support

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H.H.Koch Auditorium, Roskilde

- Background
- Danish TSOs requirements
- Overall wind farm control system:
 - Wind turbine control level
 - Wind farm control level
- Case studies with focus on:
 - Power control
 - Voltage control
 - Frequency control
- Summary

Increased penetration of wind power into the power system



Power system more vulnerable to and dependent on wind power production



Serious concern on its influence
on the dynamic behaviour of the power system.



Wind farms - active controllable components in the power system.



Controllability of wind farms
prime research concern in the grid integration of large wind farms

- Research projects at Risø-DTU National Laboratory:

- ”Operation and control of large wind turbines and wind farms”**

- (project funded by Danish TSO)*

- “Simulation platform to model, optimise and design wind turbines”**

- (project funded by Danish Energy Agency)*

- ”UpWind – Integrated Wind Turbine Design”**

- (project funded by the European Commission)*

Overall goal:

To develop dynamic models and control strategies for different wind farms technologies, with the aim to optimize their interaction and participation in the power system control according to the new grid codes.

Wind farm concepts and control:

- Active stall wind turbines
- Doubly-fed induction wind turbines
- PMSG full converter wind turbines

Grid types:

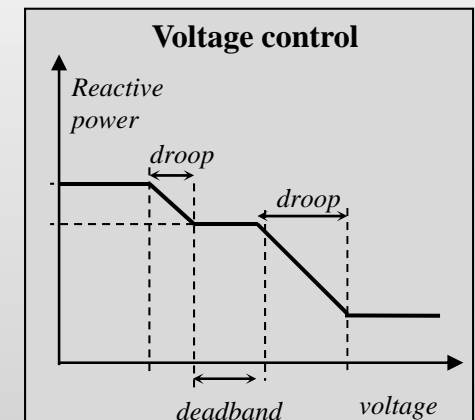
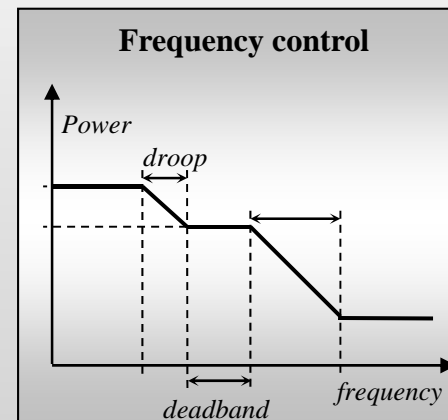
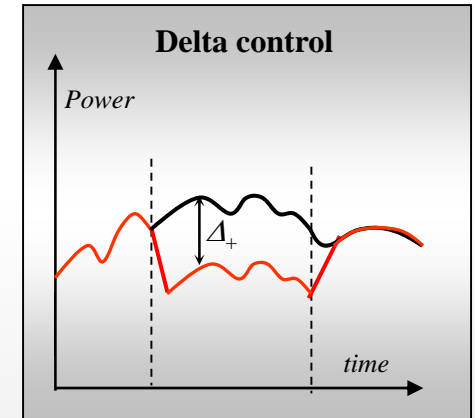
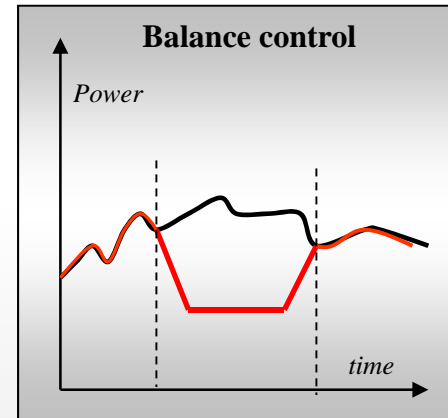
- large and strong
- small and isolated

Modelling approach:

- individual
- aggregated

Danish TSOs requirements:

- Fault Ride Through Capabilities
- Power control Capabilities:
 - Active power control functions:
 - Balance control
 - Delta control
 - Power gradient limiter
 - Automatic frequency control
 - Reactive power control functions:
 - Reactive power control
 - Automatic voltage control



Traditionally:

- to produce maximum possible power
- to reduce the structural loads on the mechanical components and thus their costs

Additionally now:

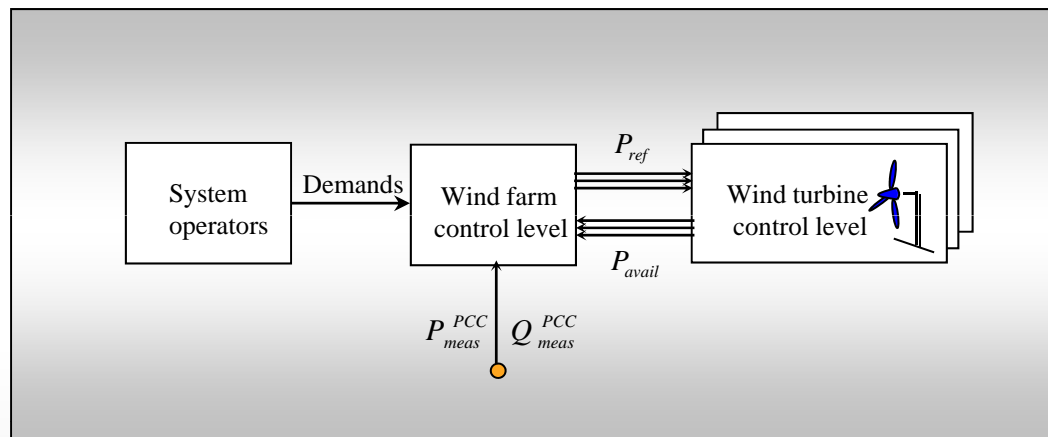
- to optimize the integration of the wind turbines in the power system, in order to secure quality, stability and reliability
- to reduce the required grid connection costs

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graph LR; A[Traditionally] -.-> B[Wind farm controller]; B <--> C[Wind turbine controllers]; D[Additionally now] -.-> C; B --> E[Grid support!];
```

Wind farm controller

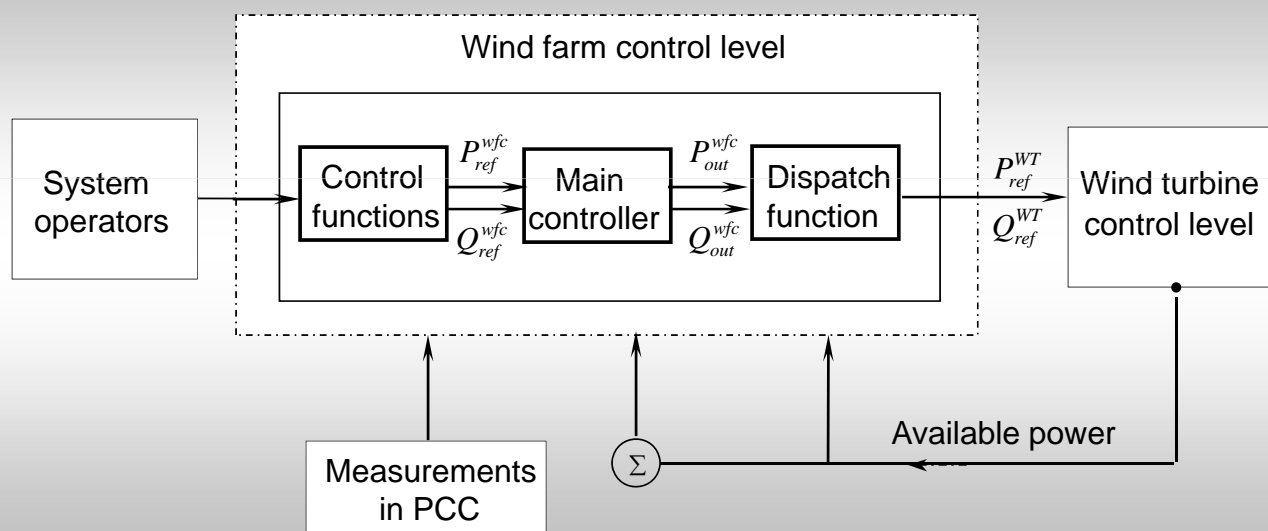
Wind turbine
controllers

Grid support !

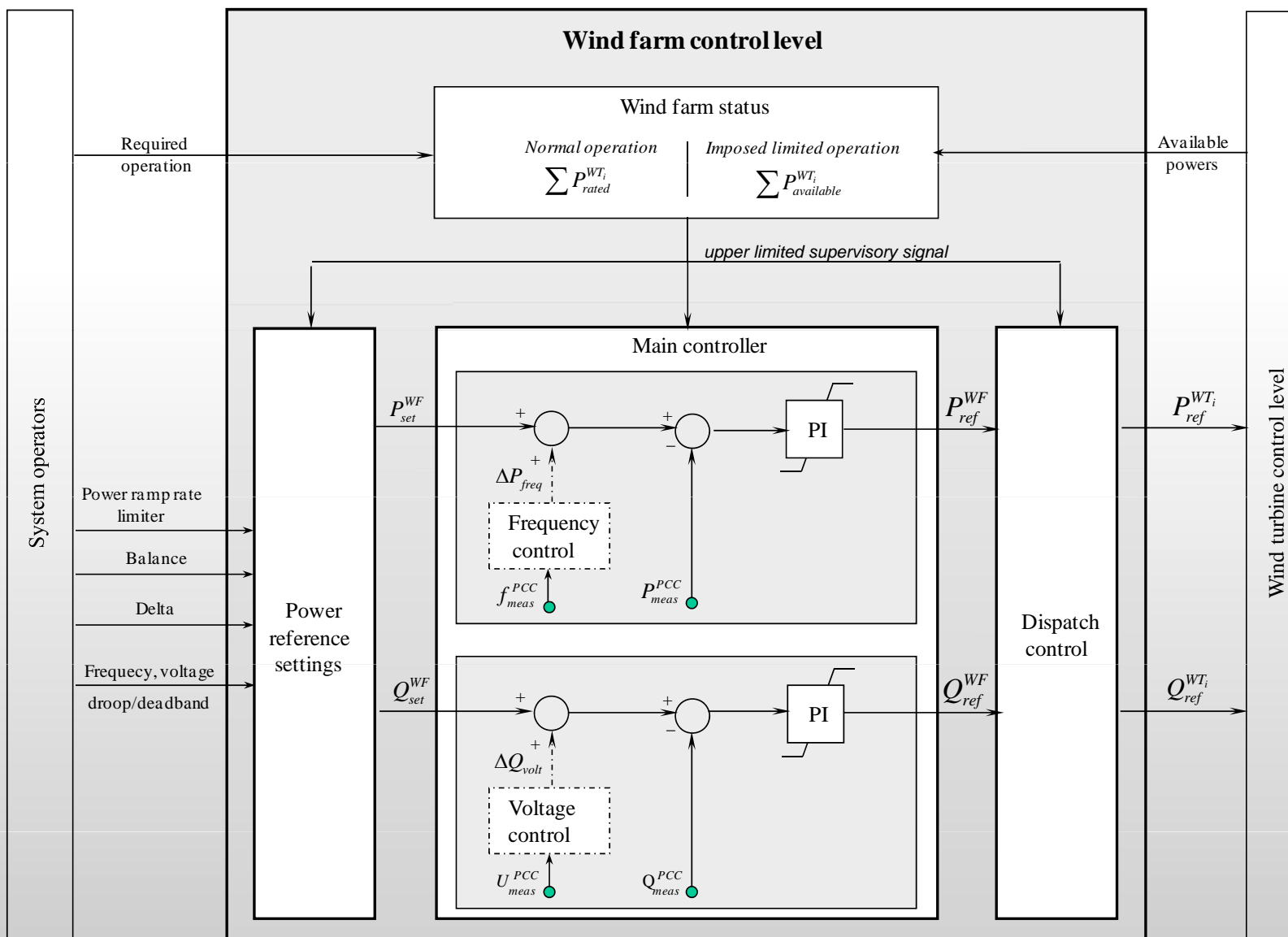


Wind farm controller's goal is to meet grid integration challenges !

System



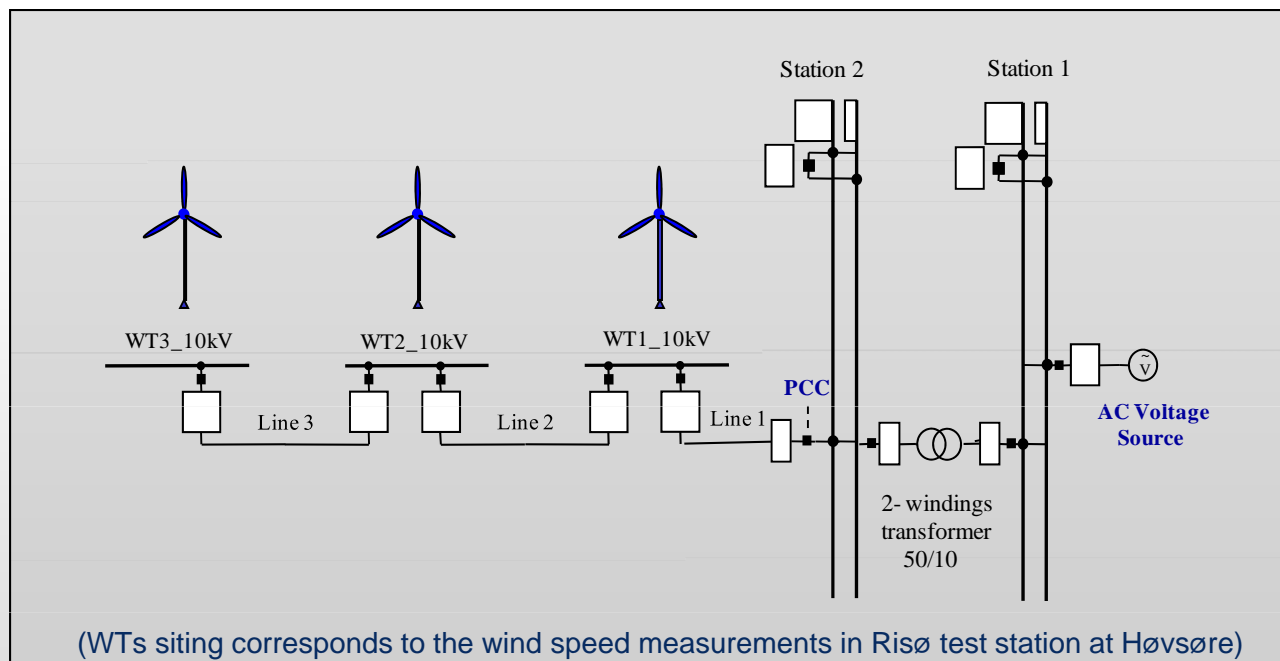
rol tasks)



Case study 1

(simple wind farm layout)

Focus on: *ability of the wind farm control to regulate downwards and upwards the wind farm production to the power reference ordered by the system operators.*



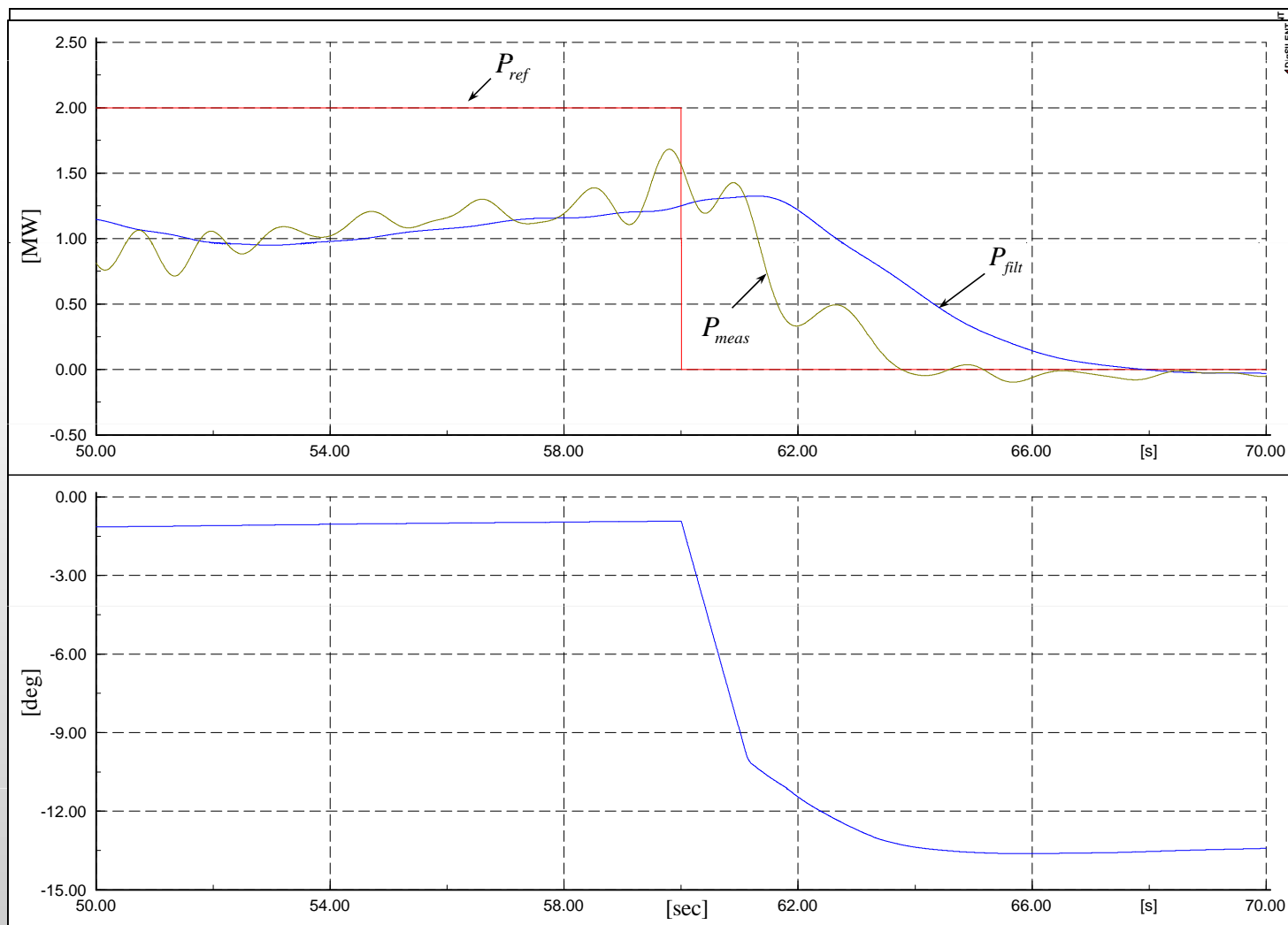
- Individual modelling approach – *focus on the interplay between WTs*

- 3 x 2MW wind turbines: **Active stall wind turbines**
or

Doubly fed induction generators wind turbines

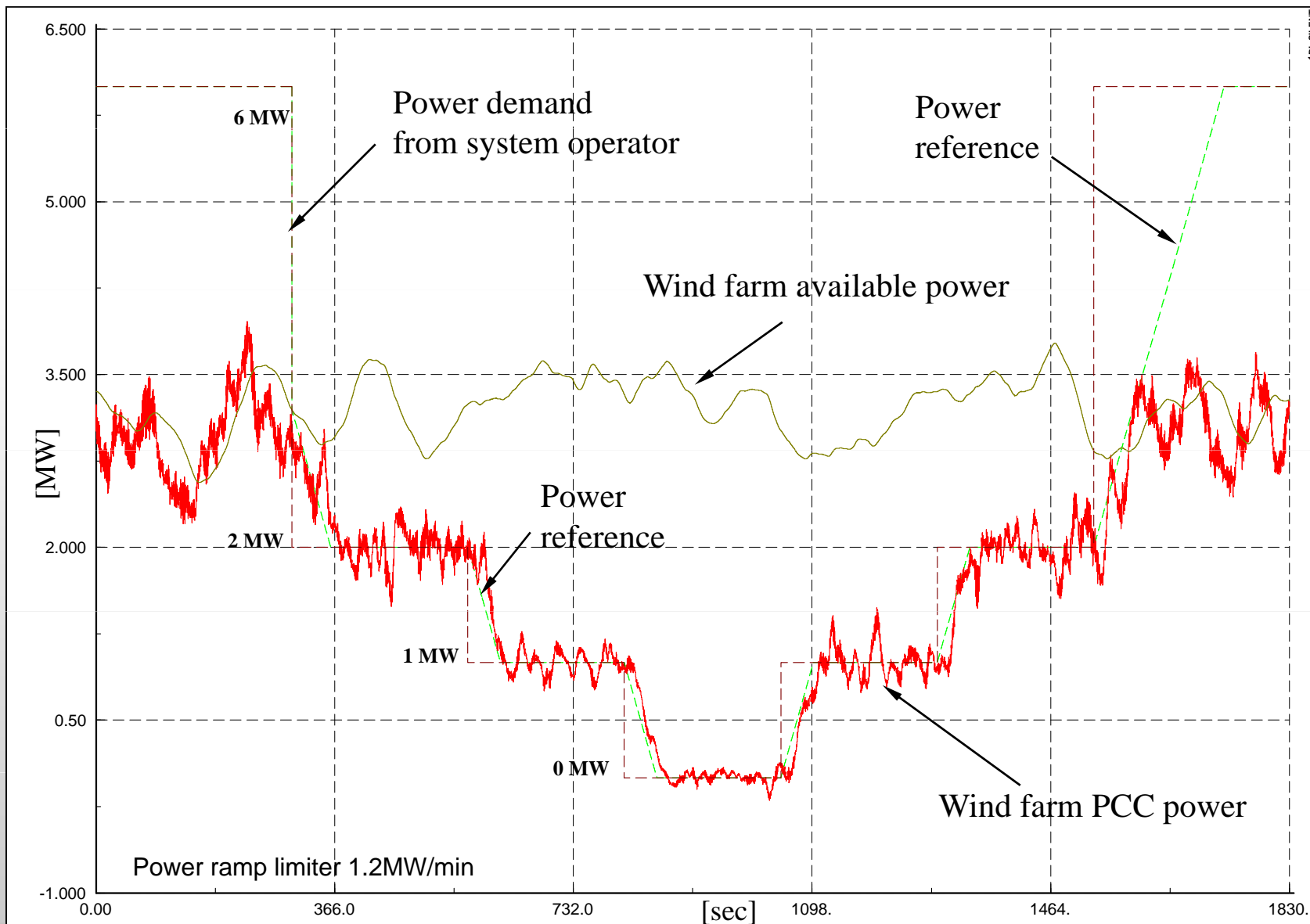
ASWTs can provide a relatively fast response to changes in active power demands !

- 11m/s wind speed
- Balance control (steps)
- Wind turbine control level



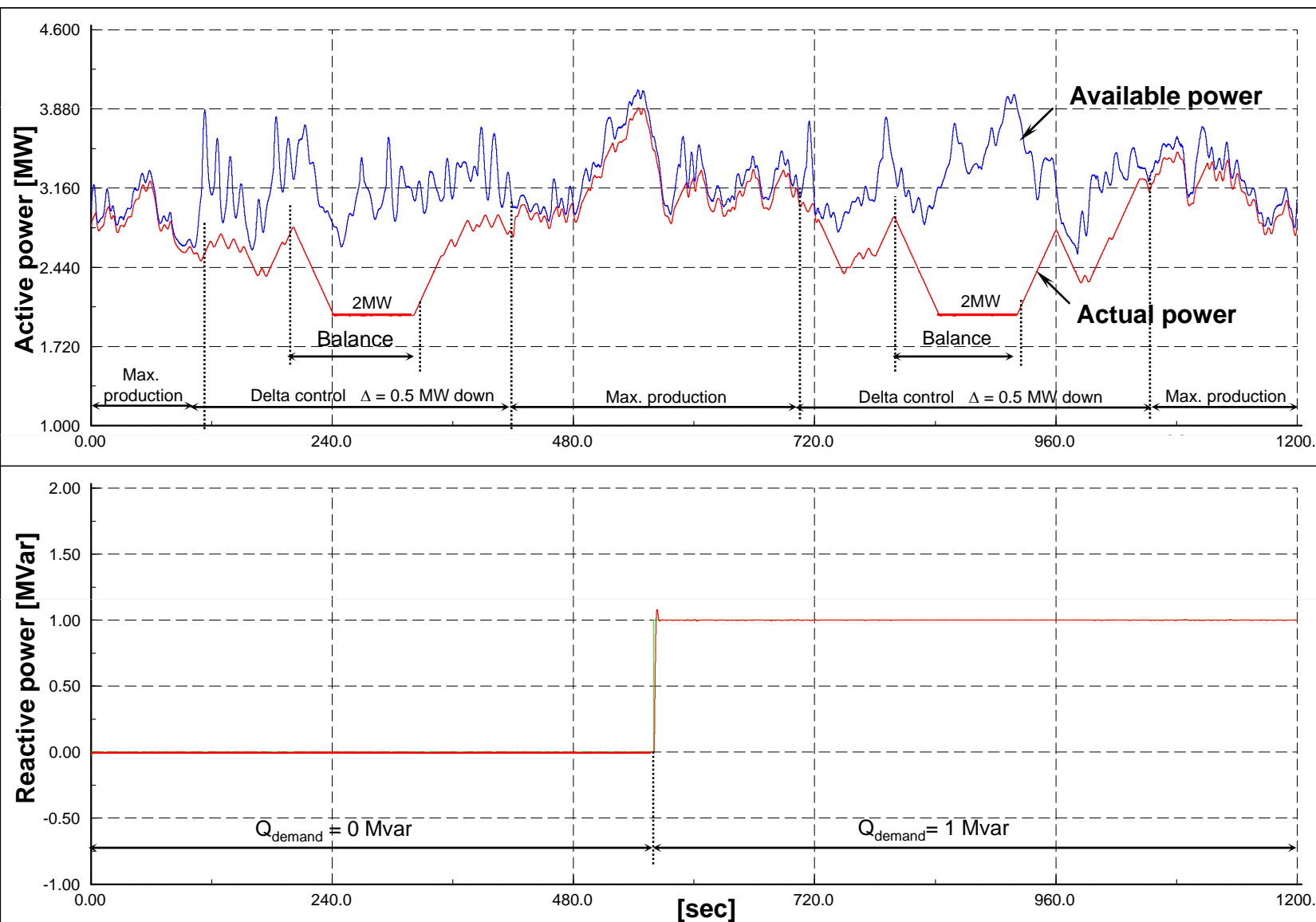
- 9 m/s wind speed
- Balance control (steps)

- Wind farm control level



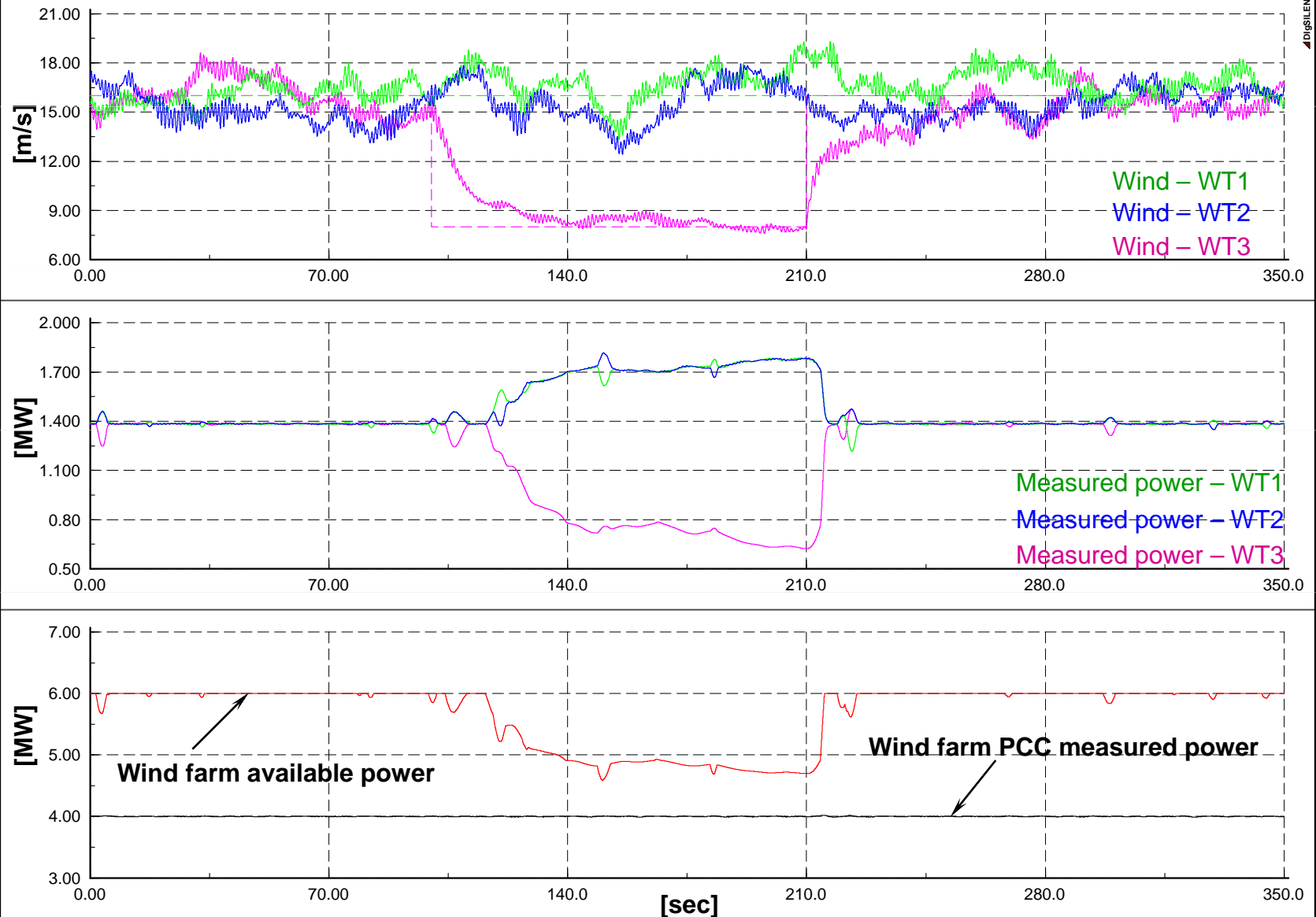
- 9 m/s wind speed
- Delta control 0.5 MW
- Balance control 2 MW

Wind farm control level

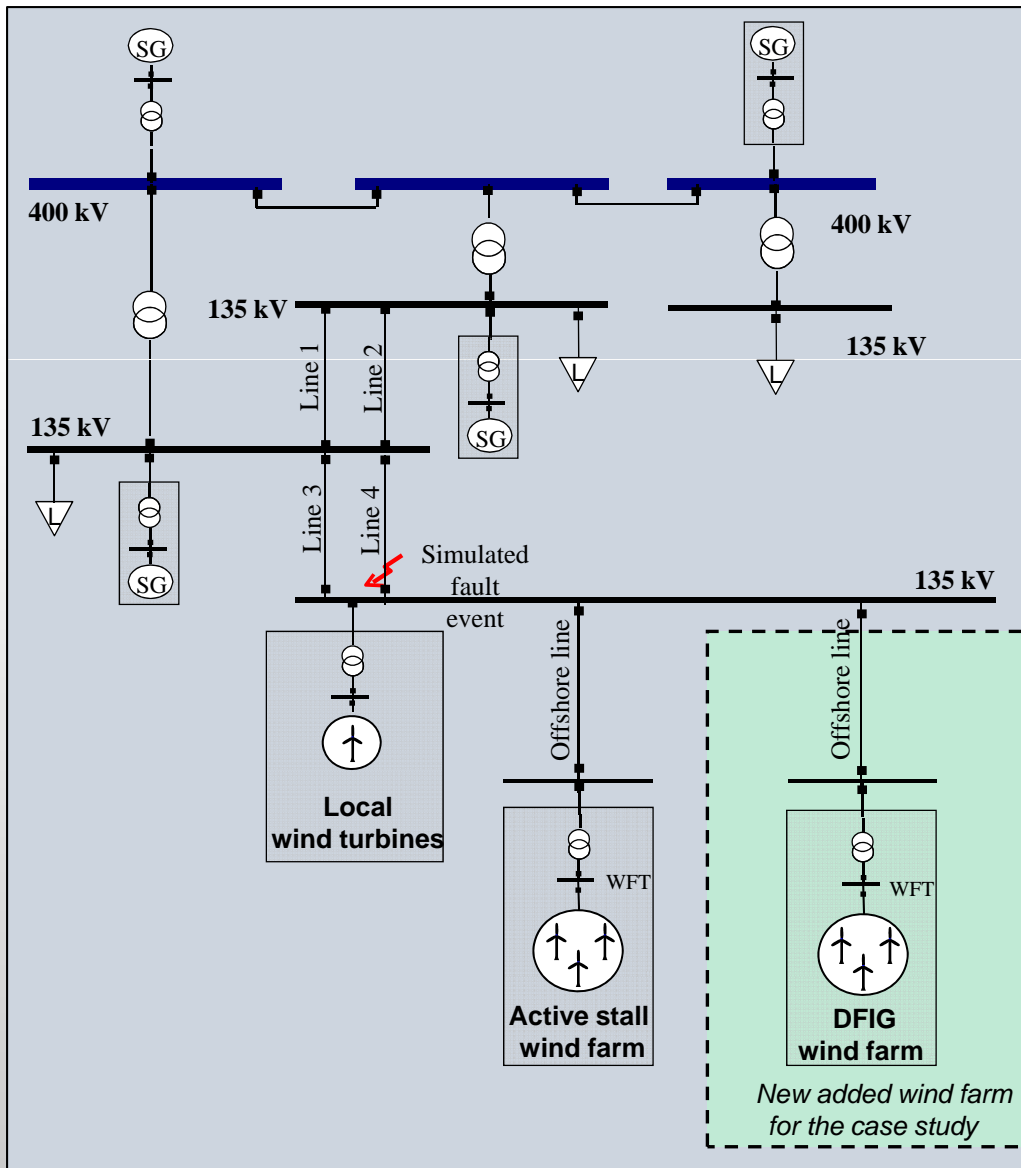


- 16 m/s wind speed
- Run in balance control 4 MW
- Reactive power 0 MVar

- Step in wind speed to 8 m/s for WT3



Focus on: *ability of DFIG wind farms to provide grid support during grid faults*



Power transmission system model:

- delivered by the Danish Transmission System Operator Energinet.dk
- contains:
 - busbars 0.7kV to 400kV
 - 4 conventional power plants
 - lumped on-land local wind turbine
 - 165 MW offshore active stall wind farm:
 - aggregated modelling approach
 - equipped with active power reduction control for fault ride-through

Extended for the case study with:

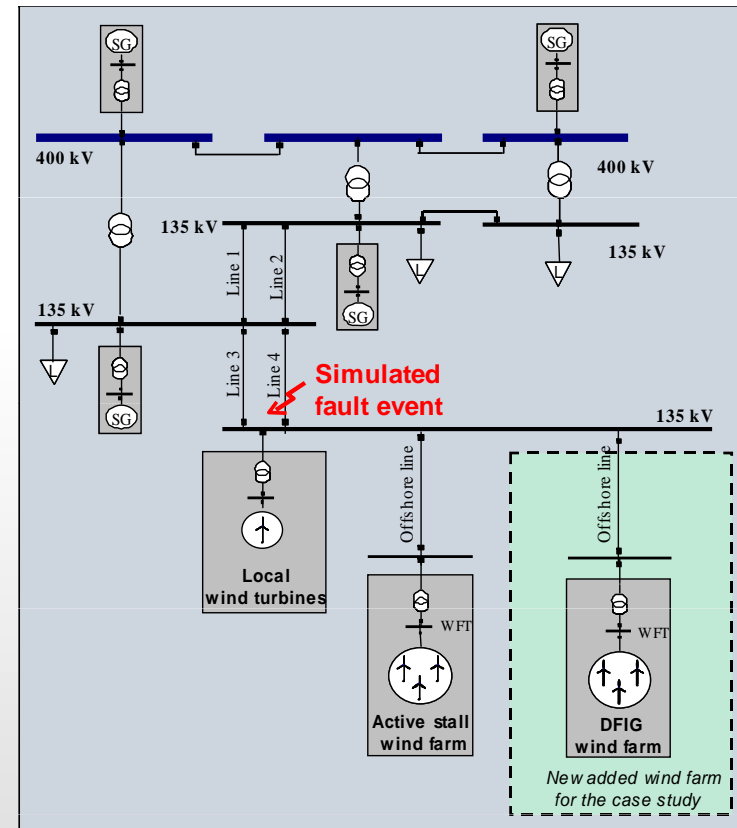
- 160 MW offshore DFIG wind farm:
 - connected to 135kV busbar
 - modelled by one machine approach
 - equipped with fault ride-through and voltage grid support controller
 - Damping controller
 - RSC voltage controller
 - GSC reactive power boosting controller

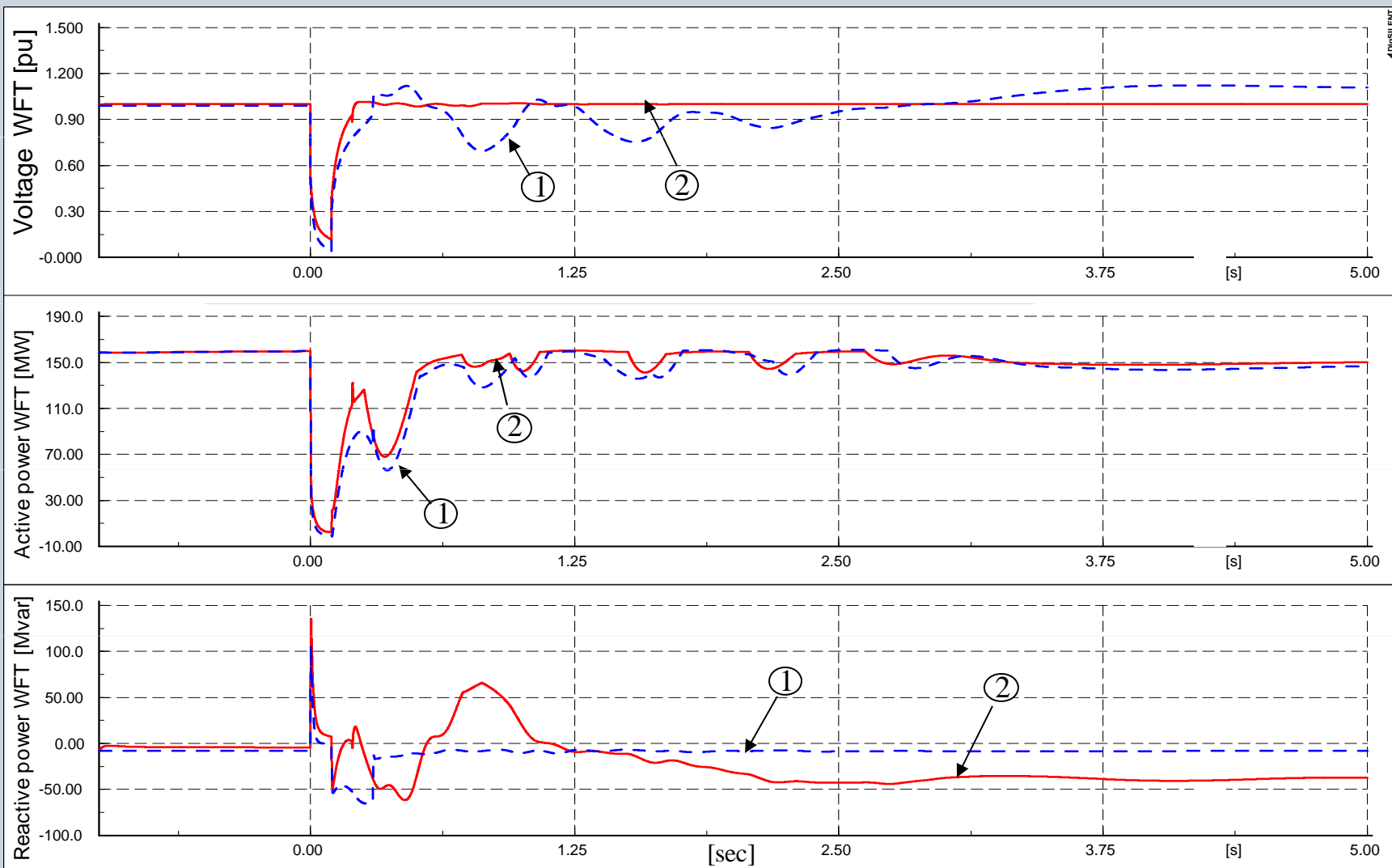
Simulated grid fault:

- 3-phase short circuit grid fault on Line 4
- Grid fault lasts for 100ms and gets cleared by permanent isolation
- DFIG wind farm operates at its rated capacity at the fault instant
- On-land local wind turbines are disconnected during grid faults, as they are not equipped with any fault ride-through control

2 sets of simulations:

- First set of simulations:
 - DFIG voltage grid support capability
- Second set of simulations:
 - illustrates DFIG voltage grid support influence on the performance of a nearby active stall wind farm





① - DFIG wind farm without voltage grid support ② - DFIG wind farm with voltage grid support

Second set of simulations

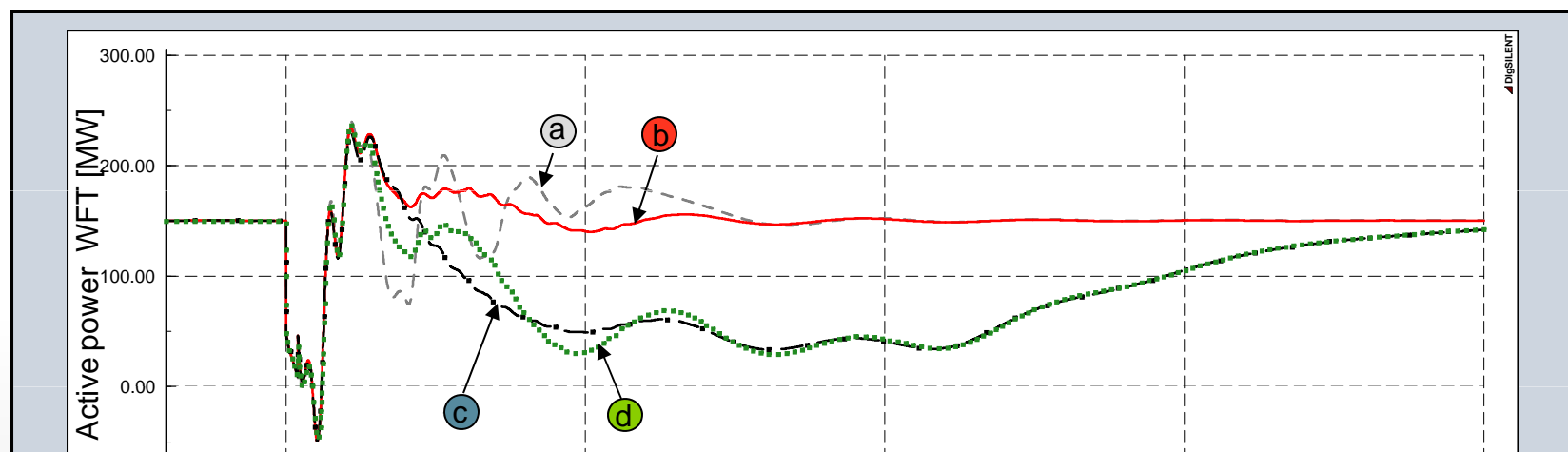
Focus on:

How DFIG voltage grid support control influences the performance of a nearby active stall wind farm during grid faults

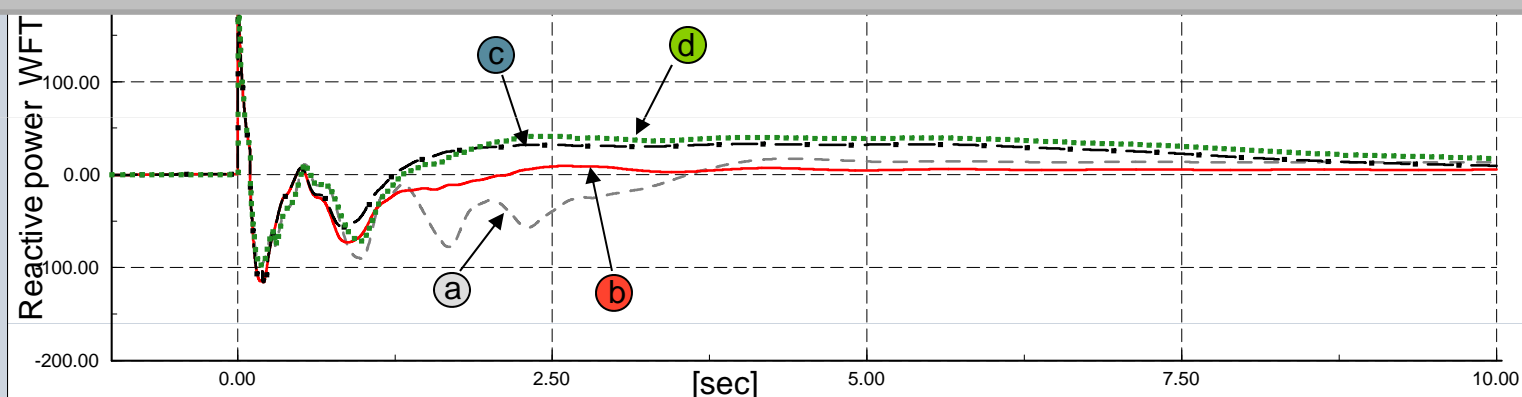
Four control sceneries are illustrated:

	DFIG WF without voltage grid support	DFIG WF with voltage grid support
AS WF without power reduction control	Scenario a	Scenario b
AS WF with power reduction control	Scenario d	Scenario c

DFIG voltage grid support – effect on a nearby wind farm



DFIG wind farm equipped with voltage control
can help a nearby active stall wind farm to ride-through a grid fault,
without implementation of any additional ride-through control setup in the nearby active stall wind farm.



(a) - DFIG-WF **without** / AS-WF **without**

(b) - DFIG-WF **with** / AS-WF **without**

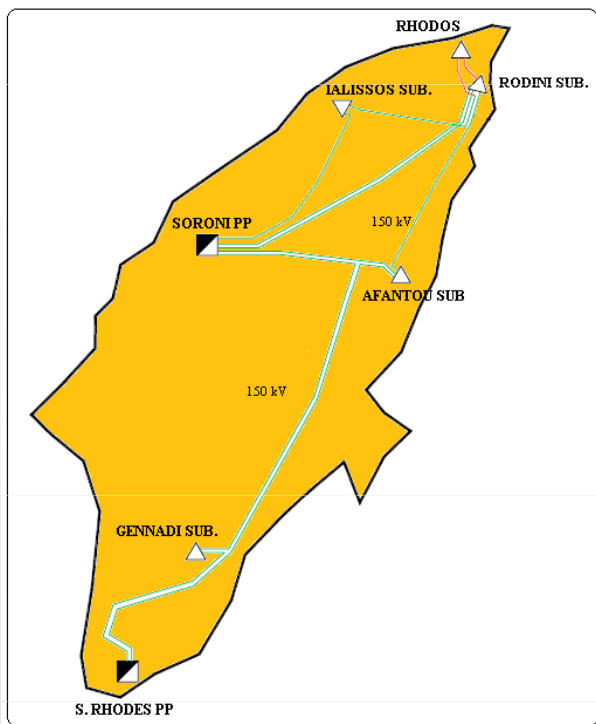
(c) - DFIG-WF **with** / AS-WF **with**

(d) - DFIG-WF **without** / AS-WF **with**

Case study 3

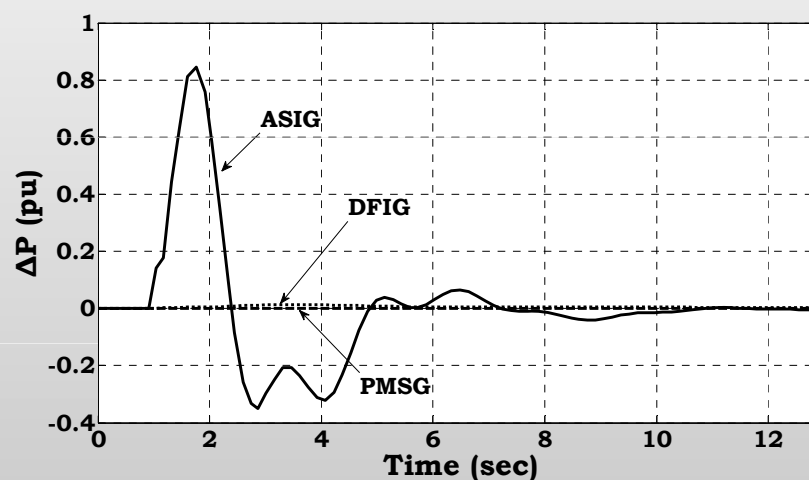
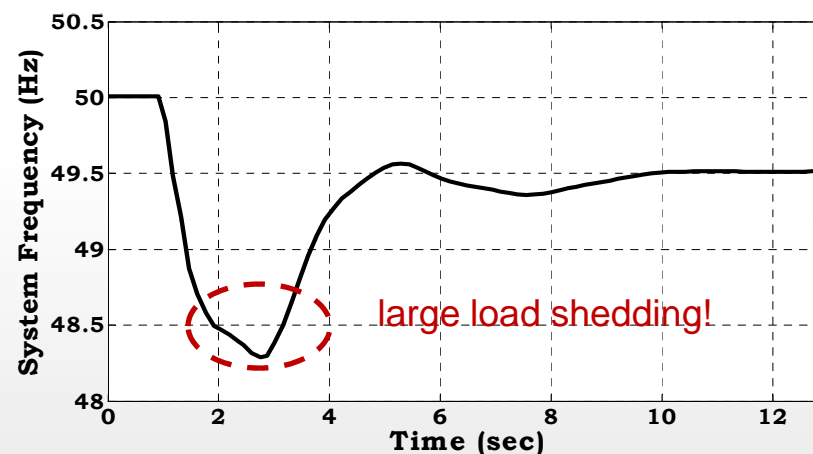
(Rhodes isolated power system)

Focus on: *active contribution of DFIG wind turbines to provide frequency control during frequency deviations in an isolated power system*

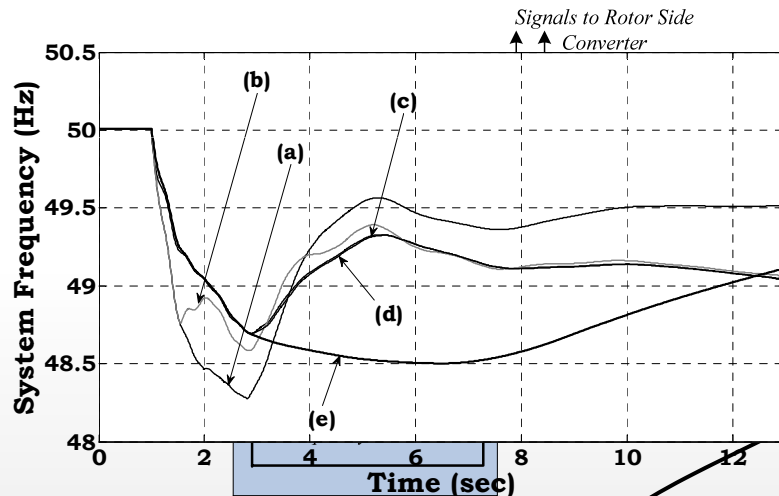


- 3 types of conventional generators & 5 wind farms (GAS, DIESEL, STEAM UNITS - ASIG, 2 PMSG, 2 DFIG)
- Aggregate modelling approach
- Scenario: Maximum Wind Power Penetration (34% of the load demand)

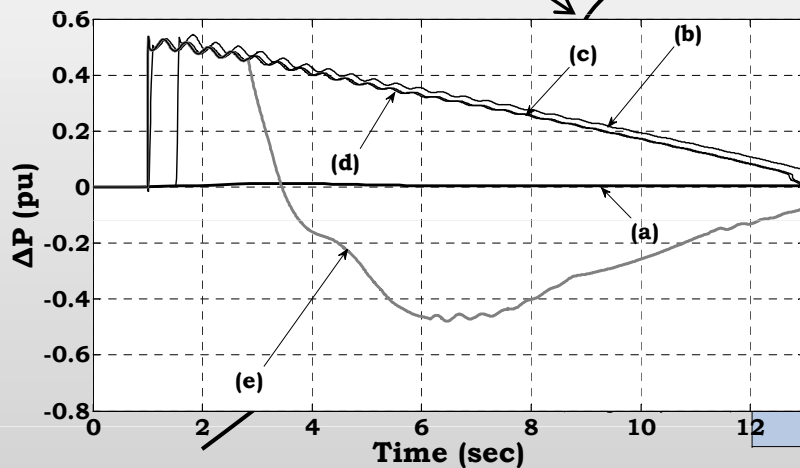
Loss of largest unit and no additional control in wind farms!



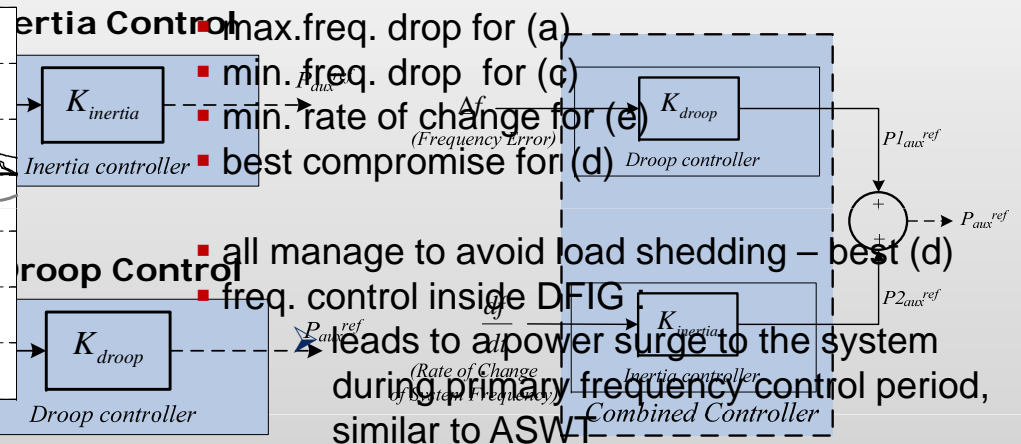
Frequency control methods for DFIG wind farms



- (a) No auxiliary control
- (b) Droop control on WF level
- (c) Droop control on WT level
- (d) Combined control
- (e) Inertia control



Remarks:



DFIG wind turbine change in active power output !

- Automatic wind farm control with grid support is a primordial issue for the grid integration of large wind farms in the future!
- Wind farm control with active and reactive power support of the grid:
 - Active stall wind farms provide a relatively fast response to changes in active power demands
 - DFIG wind farms can respond immediately to changes in active as well as reactive power demands.
 - Interplay between wind turbines inside wind farm coordinated by the wind farm controller.
- Voltage grid support - DFIG wind farm :
 - participates to properly reestablish the grid voltage during a grid fault.
 - can help a nearby active stall wind farm to FRT, without any additional ride through control setup in the nearby active stall wind farm
- Auxiliary frequency control - DFIG wind farm :
 - improves the frequency response during the first seconds following a frequency drop event
 - Inertia control: reduces initial rate of change of frequency
 - Droop control: reduces minimum frequency after the event
 - Combined control: best compromise for initial rate of change of frequency and minimum frequency
 - manages to avoid load shedding even when wind power production is higher than 30% of the demand
 - makes it possible to accept higher penetration levels for wind power

Wind farm controller's goal is to meet grid integration challenges !